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REPORT NO. GDC-DCF70-003
CONTRACT NAS 2-5571

AVAILABLE TO THE PUBLIC

FINAL REPORT
INFORMATION TRANSFER SATELLITE CONCEPT STUDY

VOLUME I • SUMMARY

GENERAL DYNAMICS
Convair Aerospace Division

FINAL REPORT
INFORMATION TRANSFER SATELLITE CONCEPT STUDY

VOLUME I ✦ SUMMARY
VOLUME II ✦ TECHNICAL
VOLUME III ✦ APPENDICES
VOLUME IV ✦ COMPUTER MANUAL

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VOLUME I ✦ SUMMARY

15 May 1971

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Prepared Under
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for

Advanced Concepts and Mission Division
Office of Advanced Research and Technology
National Aeronautics and Space Administration
AMES RESEARCH CENTER
Moffett Field, California

FOREWORD

This report was prepared by the Convair Aerospace Division of General Dynamics under Contract No. NAS 2-5571, Information Transfer Satellite Concept Study, for the office of Advance Research and Technology (OART) of the National Aeronautics and Space Administration. The work was administered under the Technical direction of the Advanced Concepts and Missions Division of OART located at Ames Research Center. Mr. E. Van Vleck is the COR for this study.

CONTENTS

ABBREVIATIONS

ETV	Educational Television
ITV	Instructional TV
CCTV	Closed-Circuit TV
CATV	Community Antenna (Cable) TV
AFRTS	Armed Forces Radio and TV Services
U.N.	United Nations
D.O.D.	Department of Defense
NDBS	National Data Buoy System
ATC	Air Traffic Control
LHNCBC	Lister Hill National Center for Biomedical Communications
FRS	Federal Reserve System
EDP	Electronic Data Processing
FBI	Federal Bureau of Investigation
NCIC	National Crime Information Center
T.Z.	Time Zone

ABSTRACT

INFORMATION TRANSFER SATELLITE CONCEPT STUDY

The contract (Contract No. NAS 2-5571) for this study was awarded to the Convair Aerospace Division of General Dynamics Corporation on 27 June 1969. Under this contract a wide range of information transfer demands were identified and analyzed. They were then combined into an appropriate set of requirements for satellite communication services. In this process the demands were ranked and re-ranked and combined into single- and multi-purpose satellite systems. A detailed analysis, assisted by the use of the Convair Communication System Synthesis Program, was performed on each satellite system to determine:

1. Total system cost, including both ground and space segments.

2. Sensitivities of the systems to various system tradeoffs.

3. Forcing functions which control the system variations.

The end-product of the study is a listing of candidate missions for detailed study along with a description of the conceptual system design and an identification of the technology developments required to bring these systems to fruition.

1

STUDY PLAN AND OBJECTIVES

The Information Transfer Satellite Concept Study was performed by the Convair Aerospace Division of General Dynamics Corporation for the Advanced Concepts and Missions group (was Mission Analysis Division) of NASA-Office of Advanced Research and Technology under contract number NAS 2-5571. This study was initiated on 27 June 1969, with completion of technical tasks scheduled for 30 September 1970 and final reporting completed by 31 January 1971. In this study the Convair Aerospace Division was supported by the Aerospace Group of Hughes Aircraft Company as subcontractor.

1.1 SCOPE

The Information Transfer Satellite (ITS) Concept Study is a broad conceptual study oriented toward developing planning techniques and tools for defining future-generation communications satellite systems and the technological developments required to bring them to fruition. NASA's role in these systems would be to conduct the technology developments programs, possibly to the extent of an experimental satellite to demonstrate the technological capability and to assess the operating characteristics of such systems.

- DETERMINE COST EFFECTIVE APPLICATIONS OF INFORMATION TRANSFER SATELLITES
  - BROAD RANGE SERVICES 1975 - 86 PERIOD
  - PROJECTED GROUND SERVICES/SATELLITES
- APPROACH
  - NEEDS RESEARCH AND SYSTEMS ANALYSIS AIDED BY A FLEXIBLE COMPUTERIZED SYNTHESIS PROGRAM (GRD/SPACE)
- END PRODUCT
  - CONCEPT PROGRAM PERFORMANCE DEFINITION
  - SUBSYSTEM LIST
  - KEY TECHNOLOGY REQUIREMENTS
  - FUNCTIONAL COMPUTER PROGRAM

As expressed by previous Stanford Research Institute (SRI) and Lockheed Missiles and Space Company (LMSC) studies, the demands for information transfer are increasing exponentially. Their accommodation represents the single largest problem for future communication systems.

In addressing the problems associated with the demands, several points should be kept in mind:

1. These are the real demands of real present users of telecommunications. Projections of the demands represent growth in these systems, present operations, some of which would be normal extensions of their present operations. These can be more quantitatively defined and represent the requirements for near-term systems. Others represent expansion of their present operations because of the potential availability of services that exceed present or planned capabilities. These are more qualitative and represent the "wish lists" or "desirements" for far-term missions. In this context many of the systems have both near and far term aspects.

2. While present users are in operation many are dissatisfied with present services because of:

   a. Cost

   b. Schedule. This applies in both the sense of timely access to present systems and timely availability of new services.

   c. Quality. Criticisms include noisy lines, fading, service interruptions, switching losses, etc.

3. While general commercial services (radio, television, telephone, telegraph) are being offered to 85-95% of the population, there are potential users who are not being served, viz:

   a. The remaining 5-15% of the population who are located in the Rocky Mountain and mid-western states, Alaska and Appalachia. These areas are typified by low population density and rugged terrain where the economics of terrestrial systems are most adverse.

   b. Special interest groups such as the professional societies, who want such services as continuing Education TV or Teleconferencing. These are also labeled as "cultural minorities" or "special minorities" in other studies. They are intermingled with the general population so the present systems must be augmented to cope with their needs.

4. There is also a significant mixture of large and small users. Typically, the large users can support their own system. However, the small user cannot easily support a system dedicated to his needs but must share a system with other small users. Compatibility then becomes the critical issue.

The ITS Concept Study has been performed in an environment of growing awareness, national and international, of the potential benefits of advanced communications satellite systems. In the period since 1962 the U. S. has progressed from a policy that supported only international systems (Intelsat) to the recently-stated policy of open competition for domestic communications satellites. On the international scene, the Intelsat series has successfully demonstrated long-haul point-to-point communications. Several countries, including Russia and Canada, have embarked on their own domestic systems. Others, like India, are moving toward experimental demonstrations with the ATS-F&G satellites.

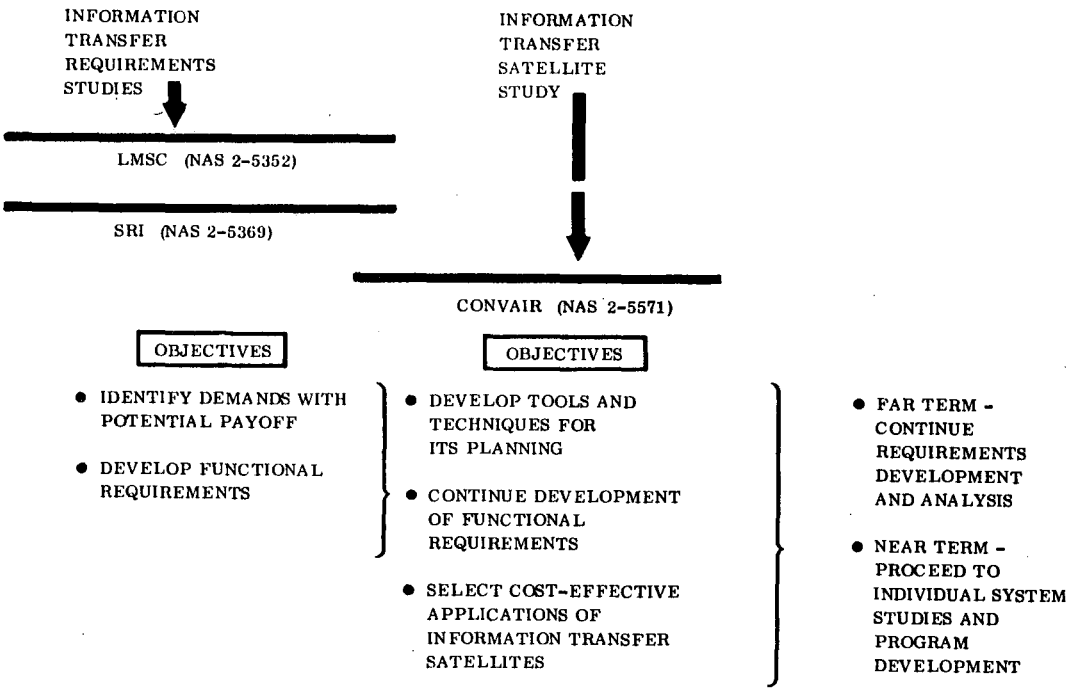
The effect of this increased interest has been to publicize the potential benefits of advanced communications systems with a net favorable impact on the conduct of the ITS Concept Study. More and more potential users cooperated by providing data representative of their systems - operating and planned. Suppliers of communications services were less cooperative in the light of the potential infringement on their competitive advantage. Both, however, fully realized the necessity for requirements development and analysis as a fundamental prerequisite to the implementation of any new system(s).

1.2 OBJECTIVES

The primary objectives of the ITS Concept Study are:

1. To develop tools and techniques that can be used in planning and preparing for advanced communication satellite systems.

2. To evaluate the demands and functional requirements developed under previous studies, but also to continue the development of this type of data.

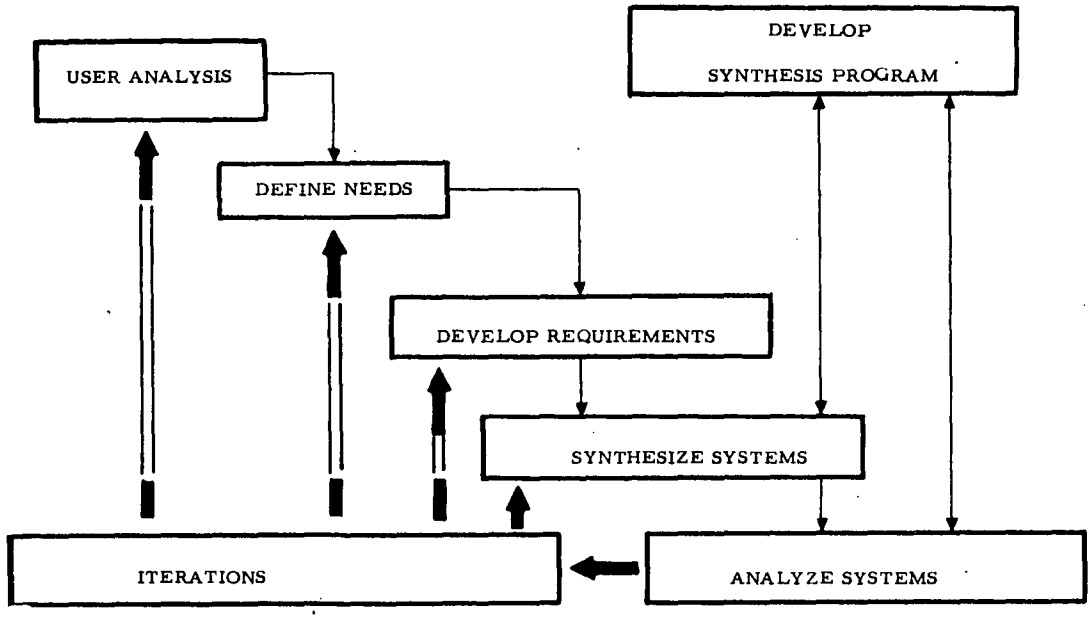


3. To synthesize satellite systems that satisfy these requirements and from these, on the basis of total systems costs, to select candidate systems for detailed analysis.

1.3 STUDY APPROACH

A classical systems engineering approach* has been applied, as shown. In this the sequence of events are:

1. Needs Research. Here the users were contacted and information solicited from them on their present operations and future plans.



2. Systems Analysis. Systems analysis properly includes the translation of user needs into functional requirements from which the communication satellite systems are synthesized. A computerized synthesis program has been developed to facilitate the complex and time-consuming calculations that must be performed. Also, because of its flexibility and ease of operation, the program permits the systems to be perturbed to show sensitivity to various forcing functions.

3. Iteration. This is one of the most significant steps in the ITS study process. It involves the call-back, renegotiation, the second chance for the user to get the full implication of his previously-expressed needs. High cost is among the factors that typically encourage (often force) compromise.

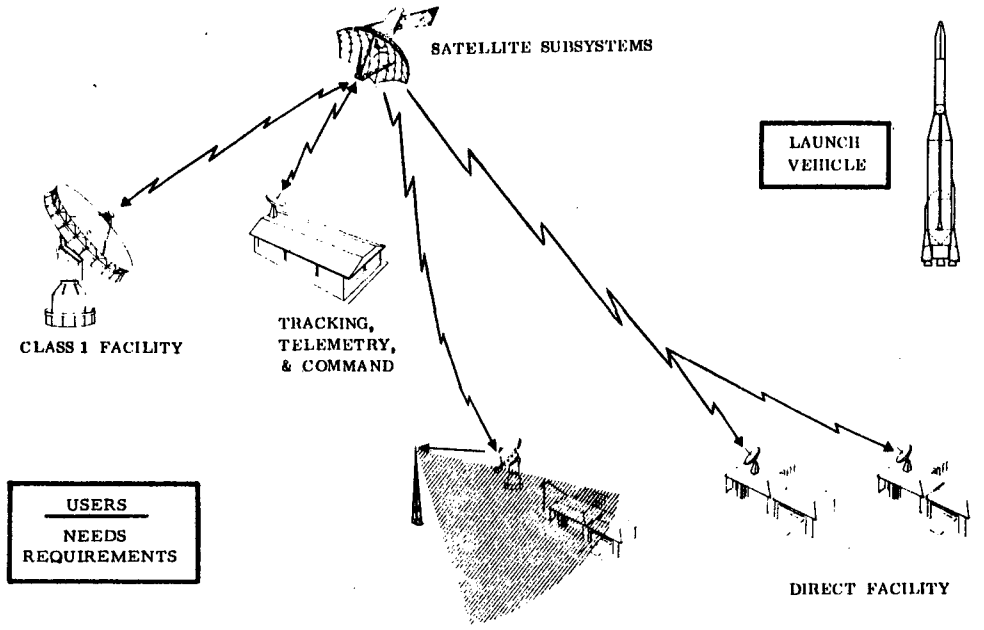
*Hall, A. D., A Methodology for Systems Engineering, D. Van Nostrand Company, Inc., Princeton, N.J., 1968.

2

STUDY TOOLS

The total system is considered in analyzing a communication system. Starting with the user requirements the system, as modeled, includes consideration of various

TOTAL SYSTEM FUNCTIONAL DIAGRAM

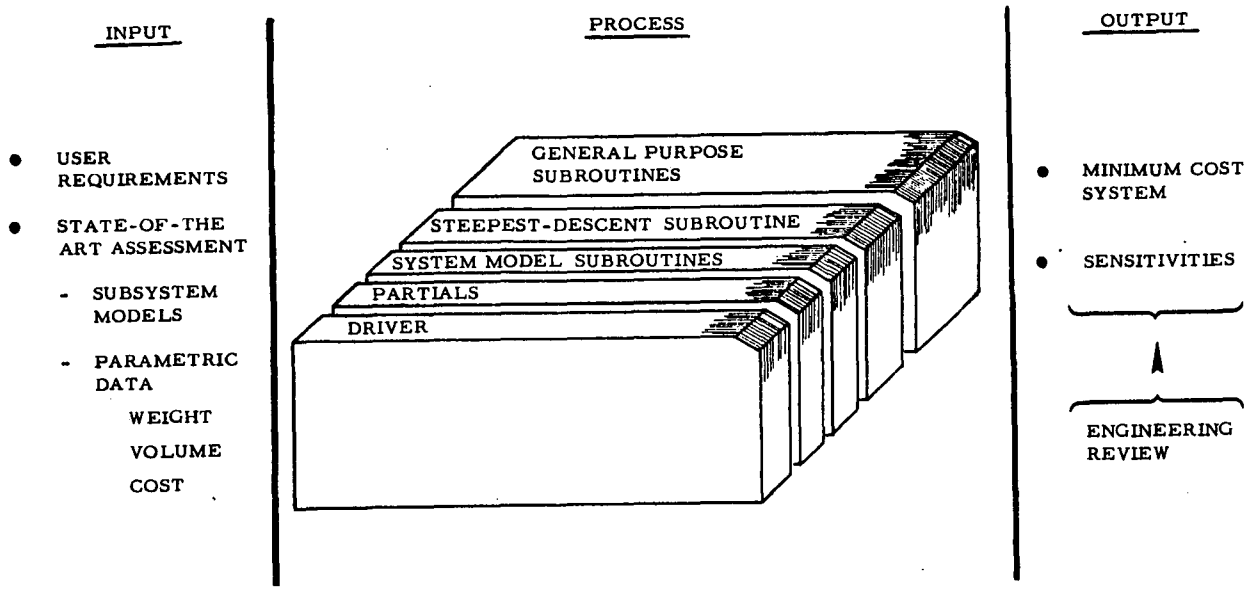


classes of uplink and downlink stations, satellite control facility, the satellite and all the appropriate RF propagation links. The launch vehicle system is also included because of the constraints imposed on satellite weight and volume. Standard launch vehicles (Atlas/Agena, Atlas/Centaur, Titan III and Titan/Centaur) were considered along with various payload options for the Saturn V. The Shuttle was not included for lack of sufficient definition.

SATELLITE TELECOMMUNICATIONS ANALYSIS AND MODELING PROGRAM (STAMP)

As shown above the synthesis program addresses itself to the total communication system from the uplink terminal(s) through to the downlink terminal(s). Inputs to the program consist of:

APPROACH



1. User Requirements. These consist of a technical description of the user system and include:

   a. User location and geographic distribution.

   b. Antenna beam characteristics (number, pointing, beamwidth, etc.).

   c. Data service (type, rate, bandwidth, transmission time, etc.).

   d. Channels.

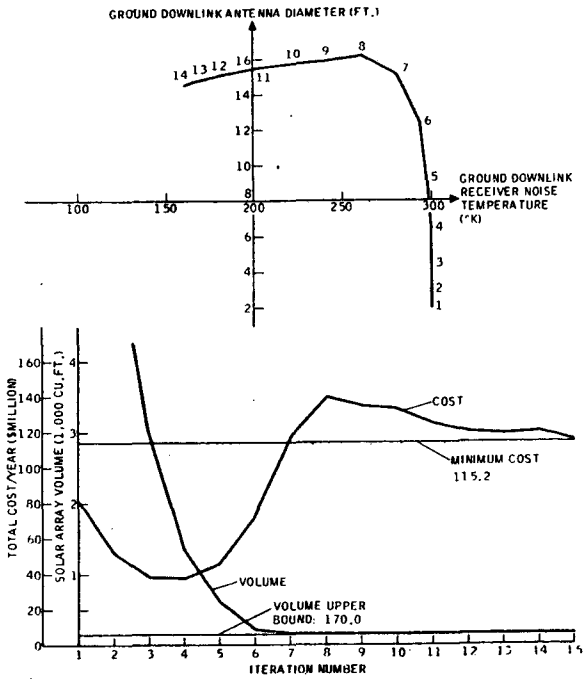
   e. Design parameter options

Signal/Noise	Thermal Control
Satellite Life	Stationkeeping
Environment	Attitude Control
No. of Ground Facilities	Battery
Up/Down Modulation	Launch Vehicle
Up/Down Frequency	Type Transmitter

2. State of the Art (SOA) Assessment. This is reflected in the type of systems and subsystems selected for modeling and in the parametric description of the systems. For example, laser communications systems are not included because of unavailability of adequate parametric data. The parametric definition of the systems and components was accomplished by assembling the available data for known equipment along with the vendors' best estimates of their projected capabilities. This provided an array of points which were then approximated with a best-fit curve.

The outputs of the program include a complete definition of the minimum cost solution to the given inputs. Perturbations can be introduced to determine the system sensitivities to key parameter variations. All of this is subject to a critical engineering review to assure that a reasonable solution has been obtained.

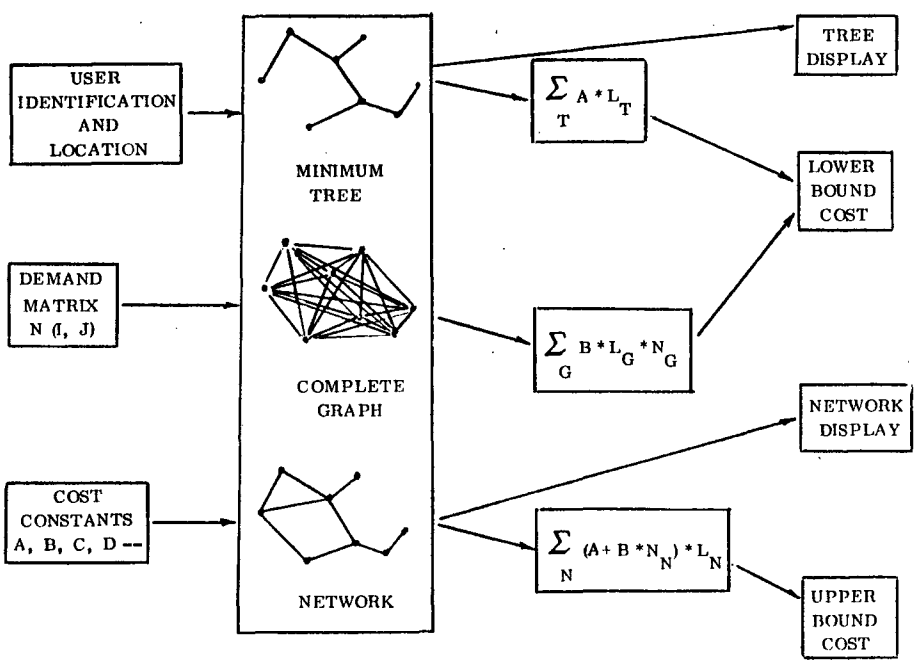
The iterative convergence of the optimization process is illustrated by the tradeoff of the Ground Antenna Diameter versus Receiver Noise Temperature in a case where a boundary was imposed by the allowable volume for the satellite solar array. As this tradeoff proceeds through 14 iterations (as noted on the upper figure, right) the volume tracks from a large violation down to the boundary in 8 iterations and holds there for the remaining 6 iterations. Concurrently the system cost has gone through a minimum of $40M/year (iteration No. 4) with a constraint violation to a minimum of $115.2M/year consistent with the constraint. Subsequently, a critical analysis of the volume boundary resulted in a relaxation that permitted a solution in the vicinity of $40M/year.



GROUND SYSTEM MODEL

Derivation of the Ground System Model (GSM) for comparison of ground networks to dedicated satellite systems required use of a network theory algorithm. Two steps were used in defining the ground network:

1. Lower Boundary Definition. Here, the centers are connected by a nominally direct path (Steiner points, the points identifying the ideally minimum path, are not derived). This constitutes the right-of-way for the network. Then the centers are connected point-to-point to meet their traffic requirements. The sum of these two elements constitutes the minimum-cost system.



It should be noted that this system is not realizable since the two elemental paths do not coincide.

2. Upper Boundary Definition. Here the primary goal is to combine the traffic and ditch paths into a near-optimum network. This is accomplished by listing the paths in the order of their length, deriving a system cost and then searching for an alternate traffic routing that results in a lower cost. If such a path is found — the original path is discarded and the traffic is combined into the new path. This network is realizable since the traffic and right-of-way paths coincide. It is not optimum since a shorter path (as represented by the interconnection of Steiner points) can be identified. However, it is sufficiently close to optimum to be acceptable for the purposes of this study without overburdening the system with the complexities of deriving successive Steiner points.

3

NEEDS/DEMANDS RESEARCH

Demands, as developed previously by Stanford Research Institute (SRI) and Lockheed Missiles and Space Company (LMSC) and by the Convair/Hughes team specifically for this study, were combined into single and multiple purpose missions for analysis. A basic series of ten missions was defined which incorporated a total of 55 demands — 31 from the SRI and LMSC studies, 24 from the present study.

SRI AND LMSC DEMANDS

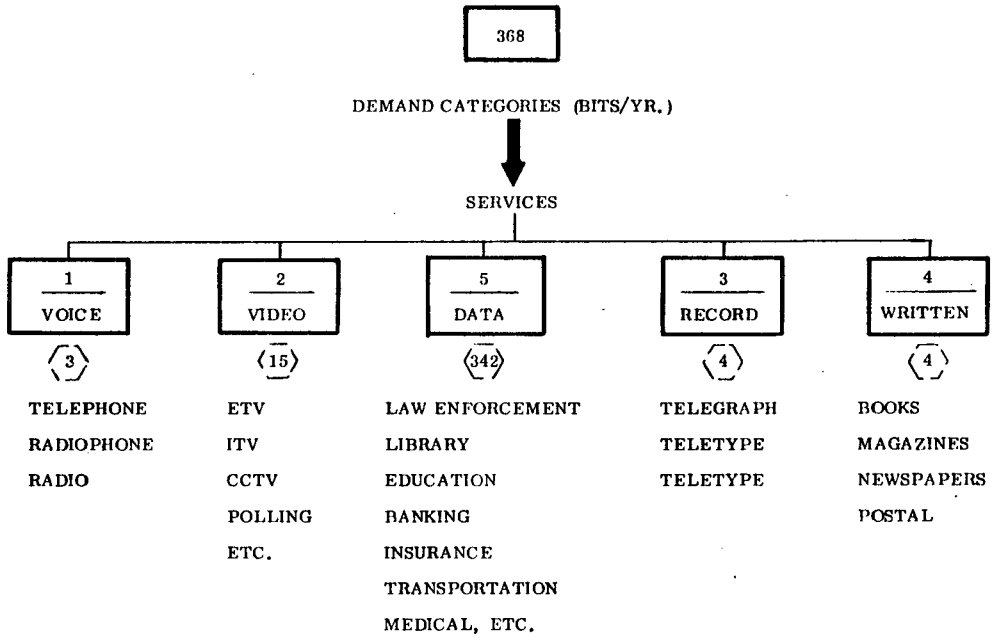
The SRI demands were generated with no constraints applied for satellite implementation. As shown, 368 demands were expressed in terms of Bits/Year as representing the total traffic requirement.

The LMSC inputs consisted of 226 identifiable demands which (along with the SRI demands) were then processed by LMSC through a screening analyses. Criteria for this screening fell into two categories:

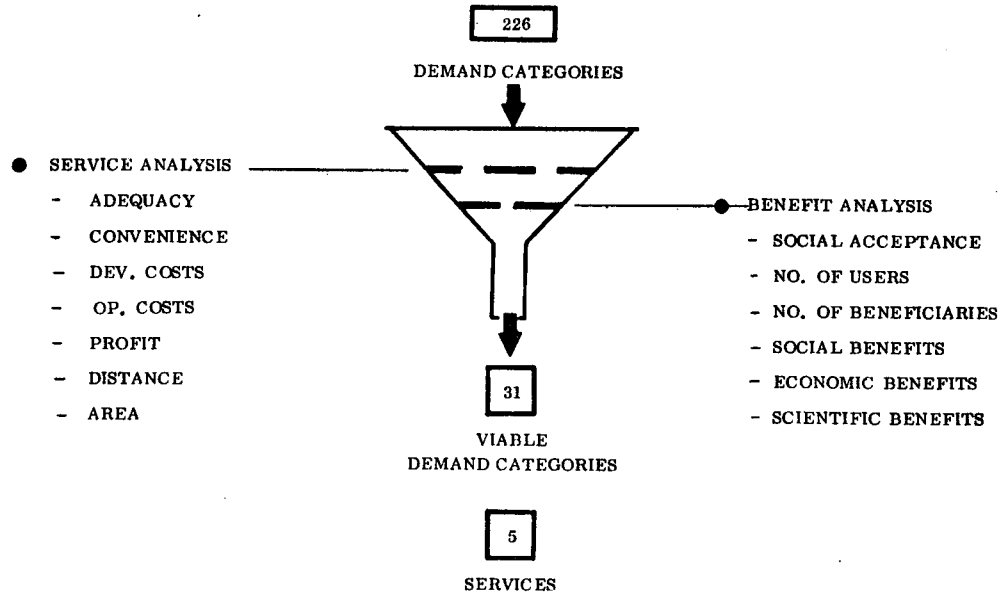
1. Service Analysis. This group addressed the problems of implementation including distances, areas, and costs.
2. Benefit Analysis. Here the emphasis was on such parameters as social acceptance, number of users and number of beneficiaries.

The end product of the previous studies was then a list of 31 demands organized into five services.

ITS CONCEPT STUDY/SRI INPUTS



ITS CONCEPT STUDY/LMSC INPUTS



CONVAIR/HUGHES DEMANDS

While this definition was being completed the Convair team also developed a list of demands, as shown in Table 1. These demands were identified and developed through a large number of personal contacts and were substantiated, to a large extent, from the current technical literature, symposia and conferences. Table 1 shows that 57 individual demands were thus identified through 288 new contacts, or 427 when repeat contacts are included. The table also shows the combination of these demands into ten mission groups on the basis of service(s) offered. These ten groups are sufficiently broad in definition to encompass the 31 demands previously defined.

This list is not meant to exhaust the entire demands of the United States nor is it an exclusive listing of service groupings. It is a list of the demands that were within the scope of the study and their resulting services. Further needs research should be undertaken to expand this list and to formulate a projection of additional and innovative services for future years.

4

SYSTEMS ANALYSIS

4.1 GENERAL

The overall approach to systems analysis has been that of a successive analysis of user requirements, near term missions and far term missions. Users exist now with

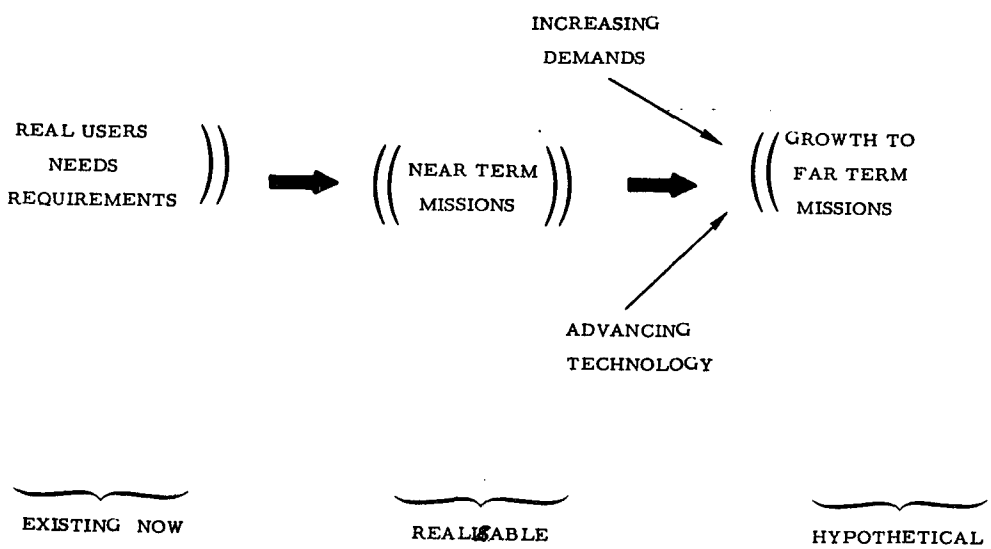


Table 1. Convair/Hughes list of demands.

MISSION GROUP	DEMANDS	NO. OF CONTACTS
1. Television Services	Commercial TV Distribution ETV Distribution CATV Interconnection ITV Distribution AFRTS	29/52
2. Remote Area Telecommunications Services	Alaska & W. States AFRTS U.N. Global ETV ETV/ITV for Developing Nations	47/98
3. Educational & Instructional Services	ETV ITV Parochial Schools Public Schools Community Colleges Institutional Interconnection Bureau of Indian Affairs D.O.D. Continuing Professional Education Adult Education	94/145
4. Data Collection & Distribution Services	Meteorology Hydrology Oceanography Seismology NDBS Earth Resources Game and Fisheries	21/29
5. Civic Safety Services	Law Enforcement Natural Disaster Warnings Emergency Communications Civil Defense	19/19
6. Travel & Recreational Services	Airline Reservations Hotel/Motel Rent-A-Car Theater Sports Camping Sites	14/14
7. Mobile Communications Services	Business Communications ATC Surveillance Maritime Freight Cars	24/24
8. Biomedical Communications Network Services	LHNCBC Regional Programs Remote Diagnosis Data Center Interconnection Remote Area Services Public Health Monitor Drugs & Narcotics Inventory Professional Update Library Browsing	17/21
9. Business Management Services	Corporate Teleprocessing Teleconferences Records/Stock/Inventory Control FRS EDP Credit Cards	19/21
10. Domestic Wideband Services	Microwave Systems Computer Services Regional Publishing	4/4
10 Mission Groups	57 Demands	288/427 Contacts

operational systems that typically fall short of their expectations in terms of either quantity, quality, cost or combinations of the three. An immediate extension of their present systems lead to the definition of realizable near term missions. A further projection of the demands coupled with projected technological capabilities leads to the definition of far term missions.

4.2 SYSTEM EXAMPLES

The following system examples are presented to demonstrate the scope of the study and the flexibility of the approach in accommodating a wide range of system topologies and variables. No attempt is made to offer these examples as final solutions to the problems they address. In fact, this would be erroneous since neither social, cultural, legal or political impacts have been included. They do represent necessary technical inputs to the decision-making process and should be considered in that light. Furthermore, some of the problems considered are highly controversial. Approaches to their solutions are equally controversial. It is hoped that this exposure of some potential solutions will lead to:

1. A dialogue (or, at least, constructive criticism) of the problem that, in turn, will lead to a better definition of the problems with more universally-acceptable guidelines for their resolution.
2. Exposure of other potential solutions which can then be included in the decision-making cycle for consideration.
3. Exposure of the other factors (social, political, etc.) that affect these solutions so that they can be properly assessed.

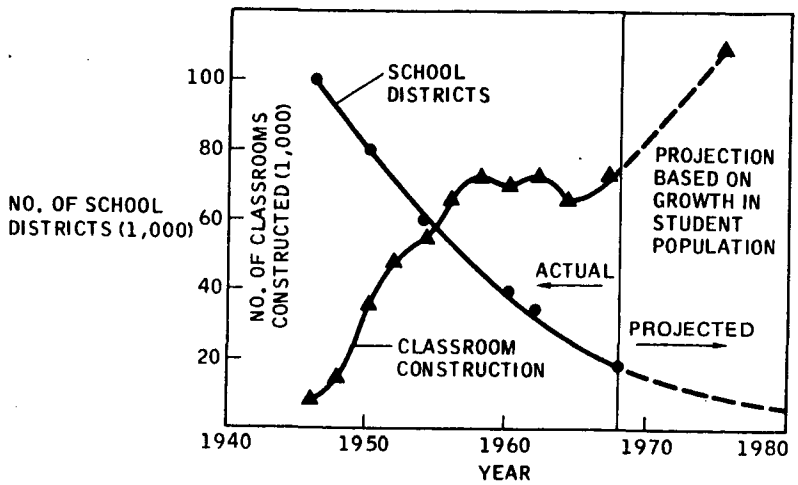
U. S. ETV/ITV SYSTEM

A combined educational and instructional television system has been postulated many times for the U. S. It is hoped that systems of this kind can help to alleviate the ever increasing costs of education. It should also help to cope with the increasing student population especially since it is not supported by an equivalent growth in teaching staff and facilities. The financial difficulties in school systems is common knowledge. School districts are facing bankruptcy and some have closed down their operations. This problem is not restricted to the public schools. Parochial schools are faced with the same problems coupled with the additional problem of decreasing numbers of religious on their teaching staffs. These are replaced, one-for-one, by lay personnel who must be paid at the same wage level as public school teachers — a further financial burden.

The growth in school facilities experienced a great increase in the post-World War II years but leveled off in the 1960's. The projected increase for the 1970's is based on a 25% increase in student population.

The problem of local control is always raised in the discussion of a national school system. As shown, there is a national trend toward unification. After World War II there were 110,000 school districts in the U.S. There are now approximately 22,000 districts.

PUBLIC SCHOOL DISTRICTS AND NEW FACILITIES *



The system postulated here is designed to serve the 200 ETV stations and 300,000 schools as shown below. The specific service, in terms of numbers of TV channels offered, was allowed to vary. Results for a total system are shown. If the entire system was to be implemented at one time, it would cost $3 - 4.5B/year. In practice it would not happen this way. The cost of the satellite and launch system is approximately $30M/year. Each of the local systems would be required to invest $150,000 in a ground

U. S. ITV/ETV SYSTEM

- SCOPE -

  PROVIDE A MULTI-CHANNEL TV SERVICE TO U.S. TO BE SHARED AS FOLLOWS:

  - ITV ------ NOMINAL SCHOOL HOURS
    8:00 A.M. TO 5:00 P.M.

  - ETV ------ EARLY MORNING & EVENING
    4:00 - 8:00 A.M. 5:00 - MIDNIGHT

- GENERAL CHARACTERISTICS -

  - ITV: ~ 300,000 SCHOOLS

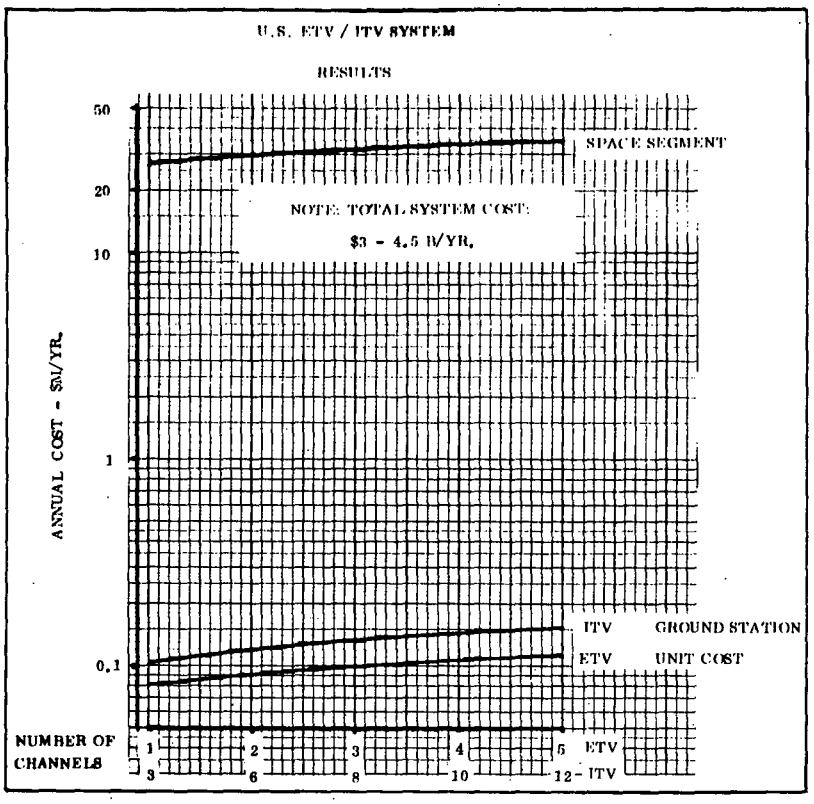
  - ETV: 176 NON-COMMERCIAL STATIONS WITH AN IMMEDIATE GROWTH TO 200 LOCAL BROADCASTS HAVE DEMONSTRATED LISTENING AUDIENCES OF 6 MILLION WITH POTENTIAL FOR CLOSE TO 60 MILLION

- SERVICE -

  NON-COMMERCIAL ETV AND ITV

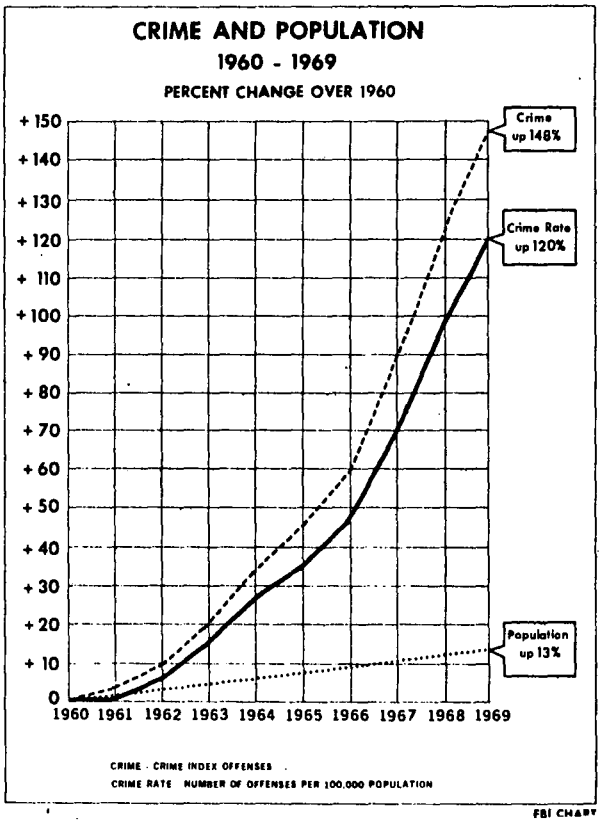
*Extracted from Digest of Educational Statistics, 1968 Edition, U.S. Department of Health, Education, and Welfare, Office of Education.

terminal. When all of the school districts and local ETV stations bought into the system the total investment would be back up to the $3 - 4.5B/year number previously stated. While this may seem prohibitive it should be noted that $50B/year is currently being spent in education in the U.S. with an immediate increase to $70B/year projected by 1975. The satellite system would constitute approximately 5% of the total expenditure.



LAW ENFORCEMENT

Increasing crime rates have increased the demands on all law enforcement agencies for more-effective protection. Of course, since some of the crimes are assaults on policemen, they have a vested interest in a more-effective protection system for themselves.* A contributing factor to the increased crime rate is the relative immunity occurring to criminals from the mobility offered by modern means of transportation. In effect this greatly increases the area and range of pursuit, investigation and search, with a corresponding increase in requirements for law enforcement communications. It lessens the apprehension rate which contributes to fewer convictions.



The FBI maintains a National Crime Information Center (NCIC) in Washington, D.C. This is connected to all of the

*U.S. News & World Report," The War Against the Police - Officers Tell Their Story," p. 82, 26 October 1970.

states through a terrestrial network (Hawaii enjoys a satellite link to San Francisco to interface with the network). This center provides data as shown. A satellite network has been postulated to expand the NCIC into a national network with provisions for connecting to the NCIC as well as between data centers located in various states. An Interrogation/Response system is presented to overcome problems associated with random access, queuing and priorities. Cities connected in the network include the state capitols plus 45 additional cities whose populations are greater than 250,000.

NCIC FILE STATISTICS
AS OF JUNE, 1970

- RECORDS ON FILE

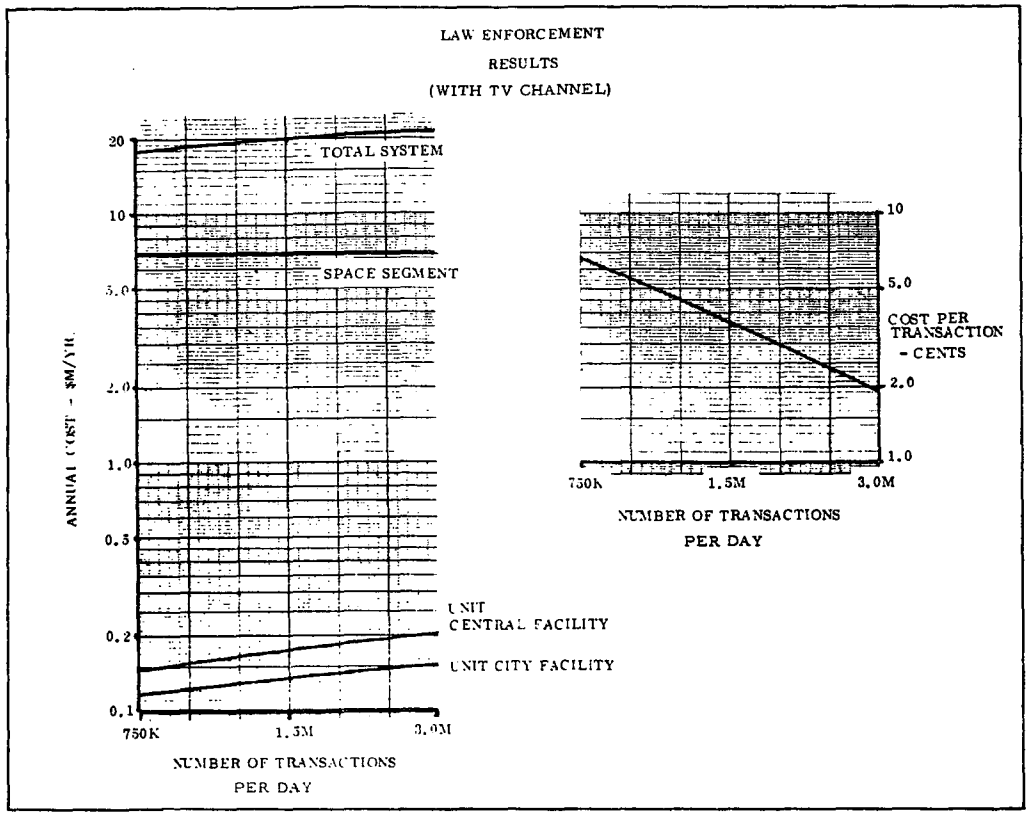
WANTED PERSONS	60,902
VEHICLES	487,780
LICENSE PLATES	160,220
SECURITIES	619,077
ARTICLES	385,156
GUNS	317,507
BOATS	1,508
TOTAL RECORDS ON FILE	2,032,150

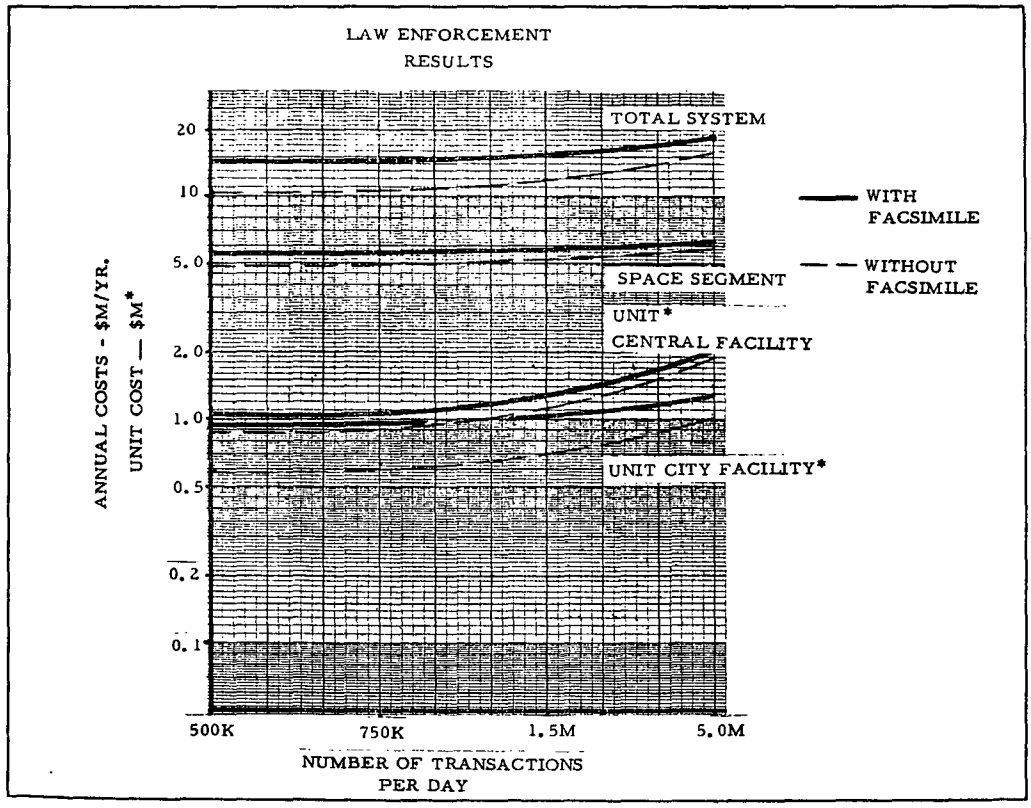
- TOTAL TRANSACTIONS FOR JUNE — 1,587,000
- DAILY AVERAGE TRANSACTIONS — 52,900

Results for this kind of system place the total system cost at $20M/year. Space Segment costs are $7M/year while the unit facility costs are on the order of $150,000 to $200,000. Of particular interest are the costs per transaction. In 1975 (750,000 transactions per day) the cost is 7 cents. By 1985 the traffic is projected to increase to three million transactions per day with a cost of 2 cents. These results include provisions for a TV channel for wideband communications. Changing this channel to a facsimile channel and, finally, deleting it altogether reduces the costs to half the original value. Transaction costs would range from a current 5¢ to less than 1¢ each.

ACCESS TECHNIQUE - INTERROGATION/RESPONSE
WITH POLLING BY CENTRAL FACILITY

- CHANNEL ALLOCATION
  - 2 CHANNELS FOR POLLING
  - 14 CHANNELS FOR INTERROGATION/RESPONSE
  - 1 ORDER WIRE FOR WIDEBAND CHANNEL
  - 1 WIDEBAND CHANNEL
- 1 CENTRAL FACILITY
- 93 CITY FACILITIES
  - 48 STATE CAPITOLS
  - 45 CITIES > 250 K POPULATION
- GROUND NETWORK FOR TRAFFIC TO SATELLITE TERMINALS
  - 750,000 TRANSACTIONS/DAY (2 MESSAGES = 1 TRANSACTION)
- 2400 BAUD CHANNELS


LAW ENFORCEMENT
RESULTS
(WITH TV CHANNEL)
TOTAL SYSTEM
SPACE SEGMENT
UNIT CENTRAL FACILITY
UNIT CITY FACILITY
ANNUAL COST - $M/YR.
20
10
5.0
2.0
1.0
0.5
0.2
0.1
750K
1.5M
3.0M
NUMBER OF TRANSACTIONS PER DAY
COST PER TRANSACTION - CENTS
10
5.0
2.0
1.0
750K
1.5M
3.0M
NUMBER OF TRANSACTIONS PER DAY


LAW ENFORCEMENT
RESULTS
TOTAL SYSTEM
SPACE SEGMENT
UNIT*
CENTRAL FACILITY
UNIT CITY FACILITY*
WITH FACSIMILE
WITHOUT FACSIMILE
ANNUAL COSTS - $M/YR.
UNIT COST — $M*
20
10
5.0
2.0
1.0
0.5
0.2
0.1
500K
750K
1.5M
5.0M
NUMBER OF TRANSACTIONS PER DAY

A system of this type can contribute significantly to accelerating the investigative process. The present terrestrial network has already been used effectively in this area. Criticism of the cost of the system must take into account the cost of crime. In 1965 alone the cost of crime was estimated at $20B. Current estimates for 1970 show this expense to be $51B per year. This figure includes $14.1B for law enforcement.

BIOMEDICAL COMMUNICATIONS NETWORK

The Lister Hill National Center for Biomedical Communications was established at the National Library of Medicine (National Institutes of Health, Department of Health, Education and Welfare) in 1968. This center has undertaken the formulation of a national communications network. Various reports sponsored by this office have suggested the need for the following services:

1. Computer-assisted diagnoses.
2. Data Bank Inquiry.
3. Library Browsing.
4. Remote Telediagnosis.
5. Medical ETV/ITV.

A system has been composed around these suggested services and typical demand requirements:

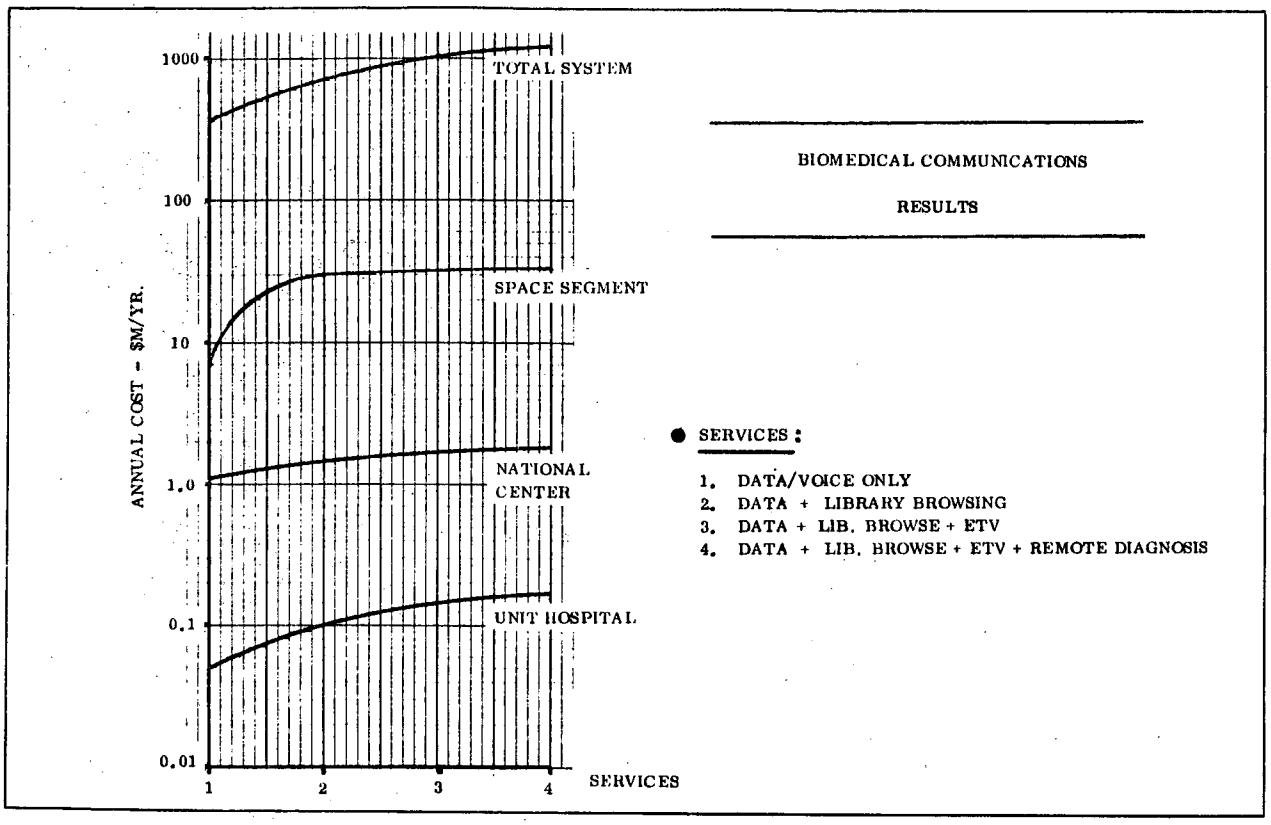
BIOMED SYSTEM INPUTS
4 TIME ZONE SYSTEM

EACH T.Z. CONNECTED TO NATIONAL DATA CENTER — WASHINGTON

TIME ZONE	NO. HOSPITALS	NO. OF DIGITAL CH.			NO. TV CH.		
		COMPT. DIAGN.	BROWSING & RECORDS	DATA BANK INQUIRY	LIBRARY BROWSING	REMOTE DIAGNOSIS	MED ETV
EAST	3450	180	90	360	6	6/OR 3-DUPLEX	5
CENTRAL	2075	84	40	168			5 AUDIO OUT
MOUNTAIN	400	10	7	23			500 AUDIO IN.
WEST	1200	40	20	80			
	7,125	100%	100%	100%	6	6 3-DUPLEX	5

When processed through the synthesis program total system costs are shown to be $400M - $1B/year depending on the services offered. Space Segment costs stabilize at $30M/year while the National Data Center (including network controls) cost is $1 - 2M/year. Cost of the individual hospital satellite terminal varies around $100,000. This system could be initiated for as low as $11M/year with individual hospitals buying in to the service at $100K each.

*U.S. News and World Report, "Crime Expense Now Up to 51 Billions a Year," p. 30, 26 October 1970.



ALASKA

The state of Alaska is unique in several ways. Its natural topology is such that it contains some of the most rugged terrain in the U.S. When coupled with the extremes of climate it experiences, it can be seen why terrestrial communication systems have not been fully implemented. Nor is there any economic incentive since the population is small and, except for a few locales, very widely dispersed, furthermore, the population is a mixture of Anglo-American, Indians, Aleuts and Eskimos with, again, a wide diversity in cultural backgrounds. As a young state Alaska enjoys a vigorous leadership which is bound and determined to get everything for Alaska that is available

ALASKA TELECOMMUNICATIONS
SYSTEM REQUIREMENTS

STATION CLASS	NO. TELEPHONY CIRCUITS		NO. VIDEO CHANNELS				NUMBER OF STATIONS	
	CASE 1	CASE 2	CASE 1		CASE 2		CASE 1	CASE 2
			R	T	R	T		
1	240	120	1-3	1-3	1	1	3	1
2	120	48	1-3	-	1	-	8	4
3	24	24	1-3	-	1	-	50	5
4	1	1	1	-	1	-	200	250

NOTE: CASE 3 — SAME AS CASE 2 EXCEPT CONSTRAINED TO INTELSAT TYPE GROUND STATIONS

in the "lower 48." In particular, communications has become a key issue. The exploitation of its natural resources and commercial interests has been greatly hampered for lack of access to the bush areas via communications. Also, the unification of the state through communications is of high interest.

Alaska has been the subject of study throughout the ITS Concept study. Most recently, in response to a Department of Commerce request, a series of special analyses was performed to assess the impact of a given set of input requirements.

Three cases were considered in which the system topology and amount of service provided changed, as shown. Results of the analysis show, for a system serving 250 stations in Alaska with both telephony and TV, Total System cost in the range of $20 - 27M/year and a Space Segment cost of $10 - 14M/year. The remaining 50% of the total cost is invested in the 250 ground stations (@ $38.6K/year) and the master control station (@ $342K/year).

In comparing the results of Case 3 (constrained to the Intelsat plan) with those of ComSat Corp. it was found that the present cost at $18M/year compared favorably with Intelsat costs at $20M/year as presented to the Public Service Commission in Alaska.

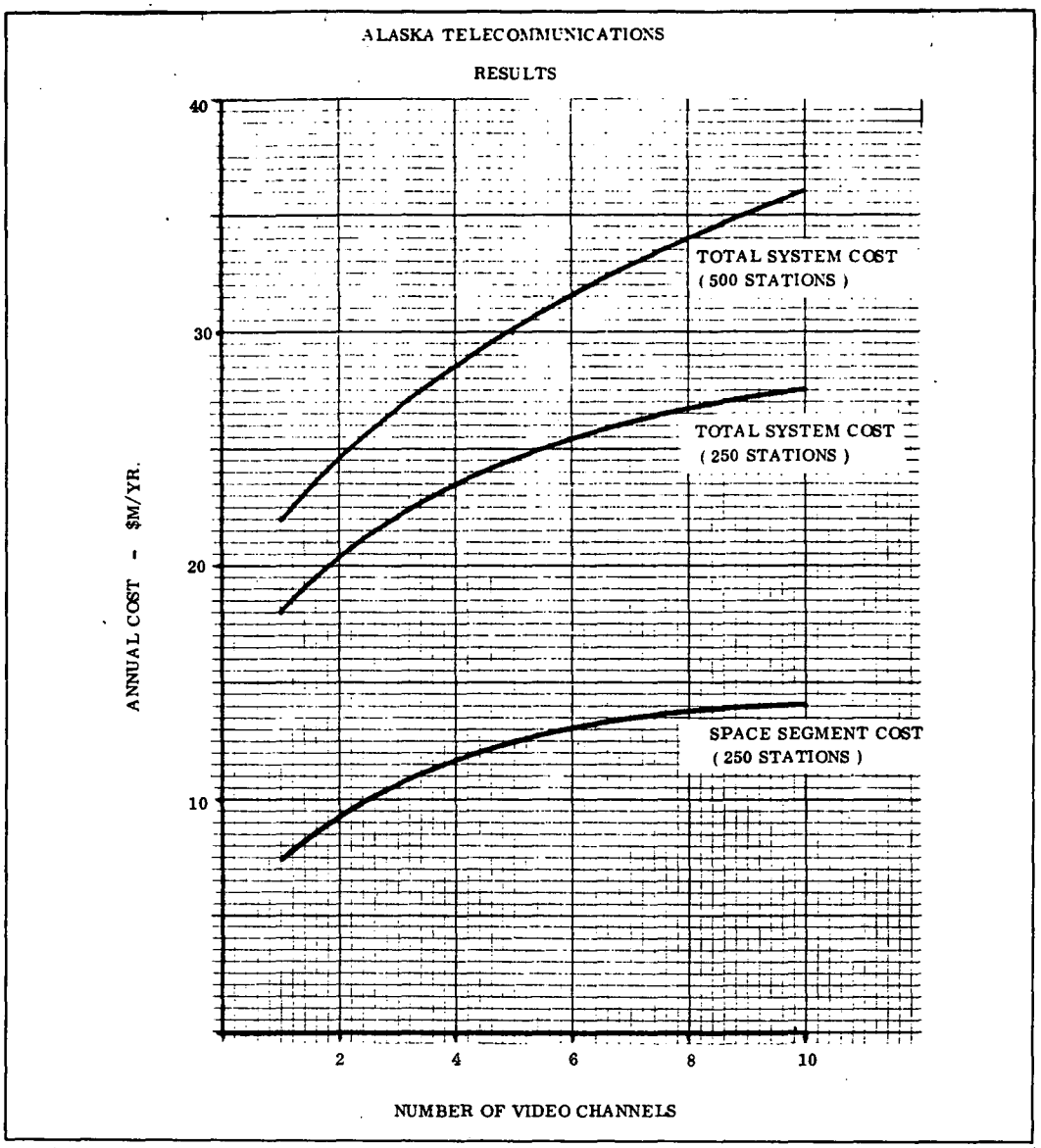
MULTIPLE-PURPOSE MISSION

The synthesis program can also accommodate a mixture of systems. An example of this operation is discussed in this section in which three single-purpose missions are combined:

1. Law Enforcement (previously discussed in detail).
2. Federal Reserve System.
3. Credit Card Authorization.

The Federal Reserve System (FRS) was instituted in 1913 by Congress. Since that time it has been the fiscal agent for the U.S. government. Of particular interest is the fact that the FRS has been operating a telegraphic wire system for money transfers since 1922. The FRS is divided into twelve districts. The boundaries were drawn many years ago and attempted to create areas of equal financial scope. That is why the western districts tend to be so large. Each district has one Federal Reserve Bank and most have several member banks.

The FRS is establishing a new communication network to accommodate its increasing traffic load. The Central Control facility for the system is located at Culpeper, Virginia, in a new underground facility. The center has dedicated direct lines to each of the 12 Federal Reserve Banks, to 24 branches and to the Federal Reserve Board and the U.S. Treasury. All traffic is sent through the store-and-forward equipment at Culpeper.



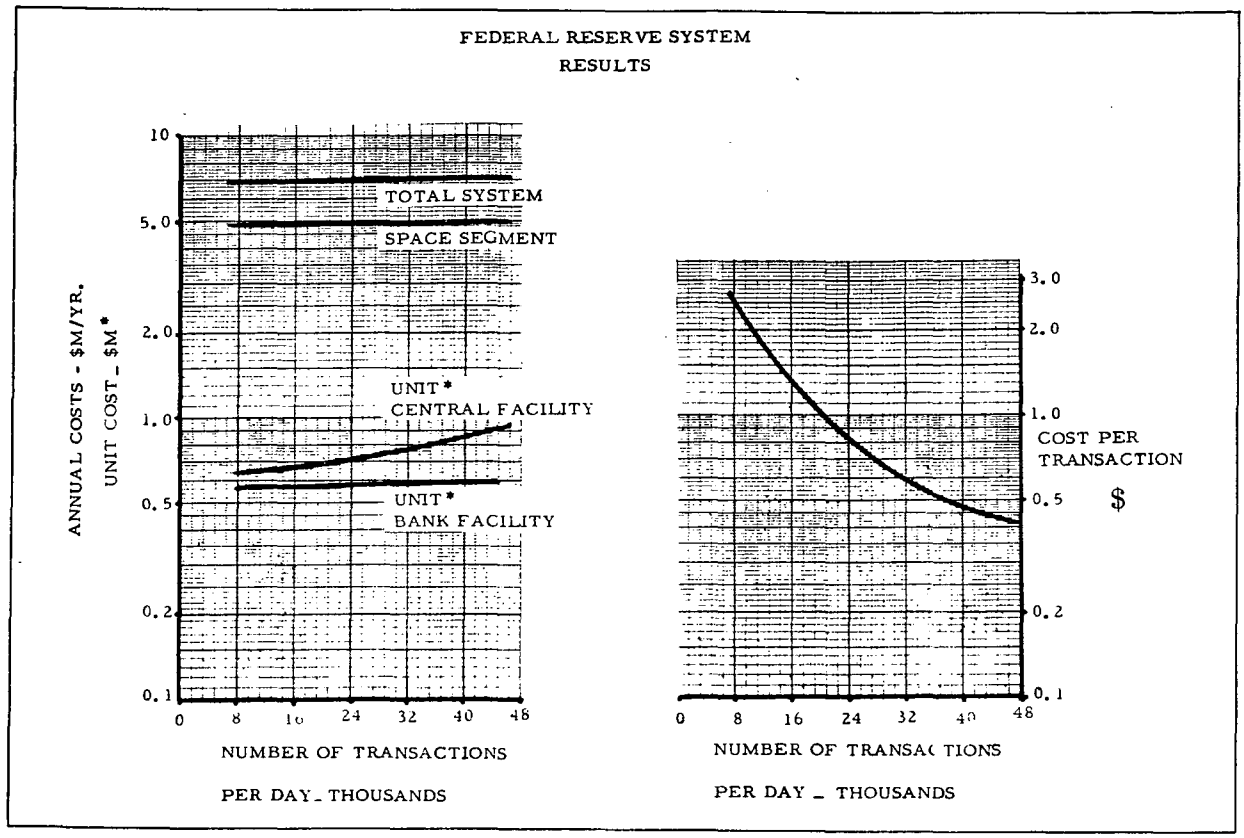
Traffic in this system is shown at 3,500 transactions per hour. It is of the Inquiry/Response type so that each transaction consists of two elements, or 7,000 messages per hour. The growth rate in traffic is estimated at 6% per year.

When analyzed by itself the results for the system indicate a Total System cost of $7M/year or a Cost per Transaction of $1.82 initially, decreasing to 40¢ as traffic builds up.

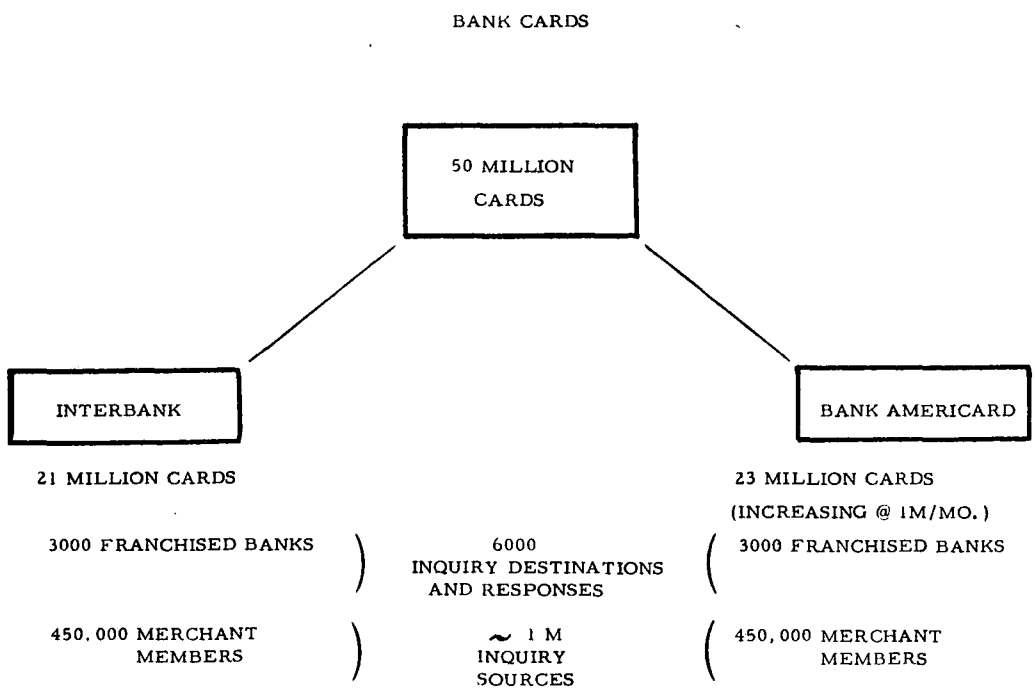
SYSTEM DETAILS

3500 TRANSACTIONS PER HOUR (3500 IN, 3500 OUT).
AVERAGE MESSAGE LENGTH:
125 CHARACTERS FOR WIRE TRANSFERS OR SECURITY TRANSFERS.
225 CHARACTERS FOR GENERAL ADMINISTRATION.
BREAKDOWN BY CATEGORY

WIRE TRANSFERS	65 PER CENT
SECURITY TRANSFERS	10 PER CENT
GENERAL ADMINISTRATION	25 PER CENT



There are approximately a quarter of a billion credit cards in use throughout the U.S. The vast majority are for retail activities (general merchandising and gasoline stations) which require local confirmation. Of interest to the ITS study are the 50 million bank cards that frequently require long distance confirmation.



These bank cards are almost equally divided between the Interbank and Bank Americard series. Each has more than 70 million cards in circulation. Each has approximately 3,000 franchises and 450,000 merchant members scattered throughout the nation.

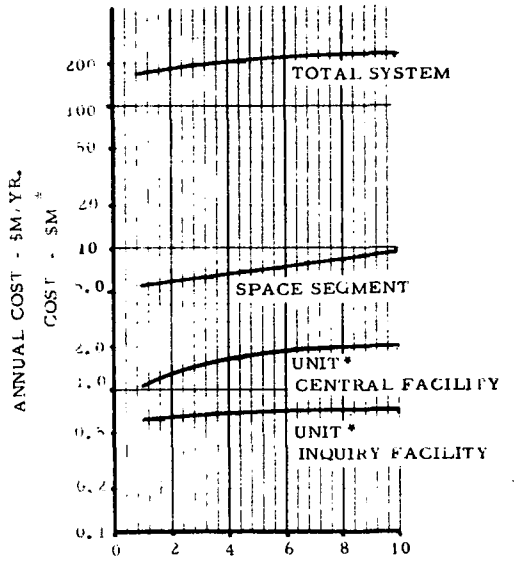
CREDIT CARD AUTHORIZATION
TRAFFIC REQUIREMENTS

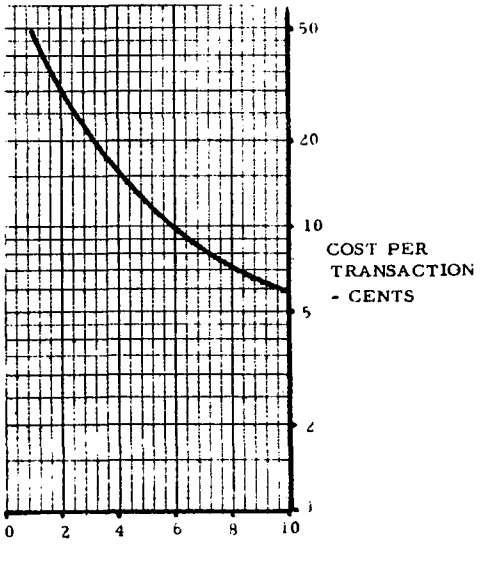
- MODEL - BANKERS TRUST OF NEW YORK
  - 50,000 INQUIRIES/MONTH
  - EACH INQUIRY ≡ 2-MIN. PHONE CALL
  - 10% LONG DISTANCE
- SYSTEM
  - SOURCE/DESTINATIONS
    - 6000 BANKS IN 3000 CITIES
    - 150 CHARACTER INQUIRY (2 MESSAGES/INQUIRY)
    - 4800 BAND CHANNELS
  - SATELLITE
    - 10 YEAR LIFETIME
    - FULL U.S. COVERAGE ANTENNA BEAM

The postulated traffic for the system is based on the Bank Americard franchise at Bankers Trust of New York. System topology is based on one Control Data Center with 3,000 cities having inquiry terminals. Each city is polled and inquiries are processed directly.

When considered by itself the Total System costs are on the order of $200M/year with the Space Segment costing $5.0 - 10M/year. The Control Center costs approximately $2M and the inquiry terminals cost approximately $700,000. Cost per transaction varies from 50¢ down to 6¢ as the traffic in the system increases.

CREDIT CARD AUTHORIZATION
RESULTS





These three systems were then combined into a single system because of:

1. Commonality of operating procedure.
2. System topology.
3. Narrow-band operations.

Comparative results for the system are shown. In the aggregate a significant saving in cost per transaction has not been achieved. However, with only a minor change for Law Enforcement and Credit Card Authorization, a 3-to-1 savings is achieved for the Federal Reserve System. This picture (for 1975) is considerably improved when the total growth in traffic is considered.

MULTI-PURPOSE MISSION

- BASIS FOR COMBINING
  - SIMILAR MODE OF OPERATIONS
  - NEED FOR QUICK RESPONSE
  - NEED FOR ACCURACY
  - NARROW BAND
- COMBINED SYSTEM
  - LAW ENFORCEMENT
    93 CITIES WITH 1 CENTRAL CONTROL
    1 FACSIMILE CHANNEL WITH ORDERWIRE
    1 DATA CHANNEL AT 4800 BAUD
    750,000 TRANSACTIONS PER DAY
  - CREDIT CARD
    3000 CITIES WITH 1 CENTRAL CONTROL
    1 DATA CHANNEL
    1,000,000 TRANSACTIONS/DAY
  - FEDERAL RESERVE
    38 BANKS WITH 1 CENTRAL CONTROL
    1 DATA CHANNEL
    11,800 TRANSACTIONS/DAY

MULTI-PURPOSE MISSION

RESULTS

	TRANSACTIONS		TOTAL SYSTEM COST $M/YR		SPACE SEGMENT COST $M/YR		COST PER TRANSACTION	
	PER DAY	PER YR.	MULTI -	SINGLE	MULTI -	SINGLE	MULTI -	SINGLE
LAW ENFORCEMENT	750K	274 M	8.15	10.9	2.3	4.9	3¢	4¢
CREDIT CARDS	1M	360 M	197.0	186.8	3.7	5.4	55¢	50¢
FEDERAL RESERVE SYSTEM	10K	3.8 M	2.3	6.9	0.27	4.8	60¢	$1.82
TOTALS	1.76M	638 M	207	204.6	6.27	15.1	32¢	31.8¢

4.3 SUMMARY

The capability of the system to accommodate a wide variety of input requirements has been demonstrated. Single and Multiple Purpose Missions can be included and the benefits of different combinations can be identified. Growth in the systems considered is handled easily and its effect can be readily assessed.

5

TECHNOLOGY REQUIREMENTS

The approach taken in this study to the task of identifying technology requirements has been that of:

1. Identifying candidate missions for satellite application.
2. Synthesizing communications systems for these missions.
3. Evaluating these systems to assess their technical implementation in terms of the present or planned state of the art at their need dates.

The candidate missions and associated satellite key parameters are summarized briefly in Table 2. The areas in which technology developments are required to permit the mission to be implemented are also shown. These are discussed separately in the following paragraphs:

FREQUENCY BAND

Many of the candidate systems require wideband transmissions to accommodate either a few TV and high-data-rate channels or a large number of low-data-rate channels. This forces the frequency of operation up about 10 GHz. The 11.7 - 12.7 GHz is the next band that will probably be made available for space services. Significant work remains to be performed in the development of space-qualified components for these and higher frequencies.

PRIME POWER

While solar array systems have been proposed for power levels up to 50 KW none have flown at power levels in excess of 5 KW. As noted in Table 2, seven of the systems require more than 5 KW and two of them require up to 100 KW. If solar arrays continue to be the workhorse for the earth orbiting missions, advanced arrays along with their system accessories (transfer mechanisms, control units, conditioning, etc.), must be developed. Alternatively, development must be initiated on appropriate SNAP isotope or reactor systems to provide this power.

RF POWER

As indicated above, components need to be developed for operation in the 12 GHz band. This is particularly true when the components that are required are in the RF systems.

Table 2. Missions groups and key satellite parameters.

MISSION GROUPS	NO. BEAMS (1)	NO. CHANNELS (2)	PRIME POWER (KW) (3)	RF POWER (W) (4)	FREQUENCY BAND (GHz) (5)	AREAS FOR TECHNOLOGY DEVELOPMENT (PER SATELLITE PARAMETERS)
1. Television Services						
a. TV Distribution	1	6 TV	14	100	12	3, 5
b. CATV Interconnection	1	20 TV	75	1,000	12	3, 4, 5
2. Remote Area Telecommunications						
a. Alaska	1	1-240 Voice 1-3 TV	3-5	25	4 & 6	—
3. Educational Services	4-8	3-12 TV	50-100	150-500	12	1, 3, 4, 5
4. Data Collection	1	1 Digital Data	1	10-20	0.4-0.42	—
5. Civic Safety	1	1 Fax 63 Digital Data	7	1,300	12	3, 4, 5
6. Travel & Recreational Services	1	18 Digital Data	5	560	12	4, 5
7. Mobile Communications Services						
a. Aircraft	1	60 Digital Data	6	52	12	3, 5
b. Ships	1	1 Voice	3	100	0.8	—
8. Biomedical Network Services	4	17 TV 1,100 Digital Data	100	1,600	12	1, 3, 4, 5
9. Business Management Services						
a. Stock Quotation Network	1	1 Digital Data	2	150	12	5
b. Federal Reserve System	1	1 Digital Data	2.4	100	12	5
c. Credit Card Verification	1	18 Digital Data	5.4	560	12	4, 5
10. Domestic Wideband Services						
a. Computer Access	1	1 Digital Data	2	75	12	5
11. Multiple-Purpose Mission (Combination of Law Enforcement, Credit Card Verification and Federal Reserve System)	3	23 Digital Data	6-10	500-1,000	12	1, 3, 4, 5

Considerable work has been undertaken by NASA in the development of "multi-kilowatt transmitters" at UHF. This needs to be extended to the higher frequency ranges to be compatible with future mission requirements.

MULTIBEAMS

Three of the missions require multiple beams for providing coverage to specified geographic areas (e.g., 4 time zones in U.S.). The multiple beams can be implemented by means of multiple antennas, multiple feeds per antenna or phased arrays. Of these, only the multiple antenna approach has been considered for operation in space (Intelsat IV). Even that has not been operated in the 12 GHz frequency band. Proposed phased array are for narrow-band systems. Their operation in wideband systems is questionable in terms of phasing characteristics and frequency response over the total bandwidth.

STABILIZATION

Not specifically shown in Table 2, but of concern is the effect of the long life requirement of most systems on the attitude control and stationkeeping system. Ion propulsion is the most cost-effective system for these purposes at lifetimes greater than 5 years. This is particularly true when considering high-powered systems requiring tri-axial stabilization. Considerable effort beyond that so far expended on the SERT systems needs to be put into the development of a family of thrusters with an appropriate range of impulse.

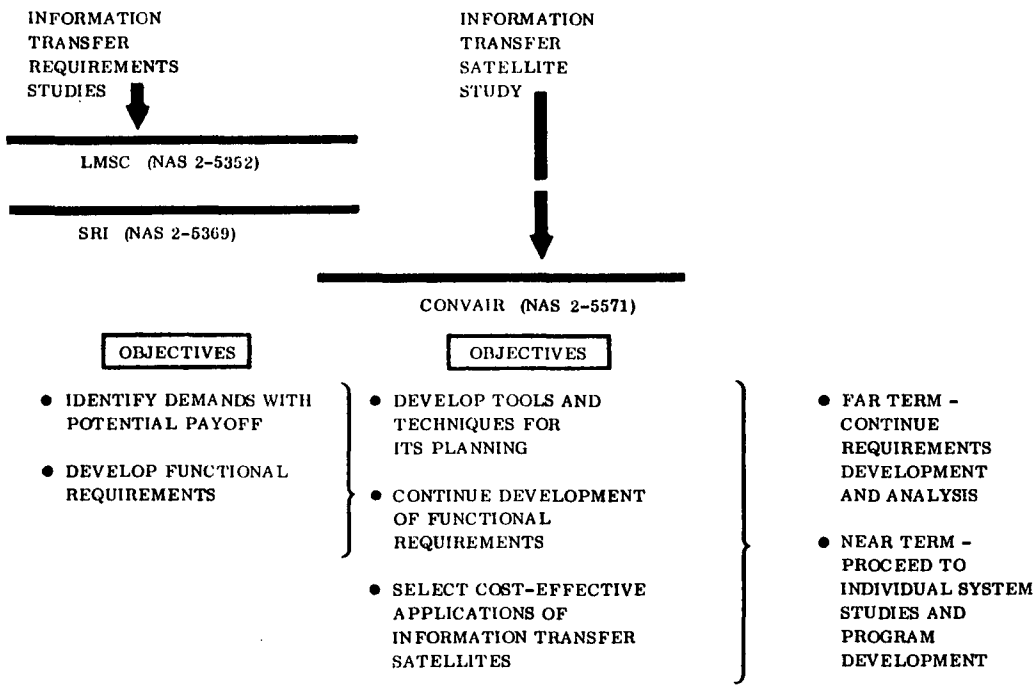
GROUND TERMINAL

Most of the systems identified so far in the study have a large population of potential users. Furthermore, in most of these systems, more than 50% of the total system cost is attributable to the procurement, operation and maintenance of the ground terminals — uplink as well as downlink. This is an area that could benefit greatly by the development of low-cost, high-reliability and easily-operated ground terminals. A significant start has been made by NASA for TV systems. This should be extended to include low-cost multi-mode terminals.

6

CONCLUSIONS AND RECOMMENDATIONS

A review of the ITS Concept Study in terms of the original objectives indicates that these objectives have been met and, in part, exceeded.



PLANNING:

The basic objective here was to develop a methodology for making contacts with potential users to elicit their communications needs. This has been done to the extent of 288 initial contacts over a wide range of demands. This shotgun approach was taken deliberately to have as broad a data base as possible. Two points should be made:

1. The field of user contacts is by no means exhausted. Each contact made produced several referrals so that the scope is still diverging.

2. This was not undertaken in depth. If a scale of 0 to 10 were to be applied to the level of penetration into the detail of user needs, it is estimated a level of 3 was reached.

The other part of this objective was achieved by the development of two computer programs. The Communication System Synthesis Program addresses the entire communication system and derives a minimum total cost solution. The proper balance between

the segments of the system can then be displayed. When checked against Intelsat IV the results came within $2M of that system's projected cost.

The Ground System Model is not as complete as the previous program but it does provide a near-optimum solution for ground networks based on telephone lines, cable or microwave systems. A complete model of the switching and control terminals was not attempted. When compared to the DATRAN requirements this model generated a network whose costs for right-of-way and links/channels were within 15% of DATRAN's costs for these elements. (Data Transmission Company)

APPLICATIONS

A series of 10 basic mission groups was identified as candidate missions for the late 1970's and 1980's. All of these have long term implications. A few also have near term implications worthy of separate detailed study. They are:

1. Remote Area Telecommunications Services.
2. Educational and Instructional Services.
3. Civic Safety Services.
4. Biomedical Communications Network Services.

RECOMMENDATIONS

1. Continue the planning activities to, at least, include the cultural, social, legal and political impacts of the candidate systems.
2. Continue the long term analysis of candidate missions, including the definition of further missions.
3. Undertake detailed study of the following missions:
    a. Remote Area Telecommunications Services — In particular, study the specific application to Alaska and the Western States.
    b. Educational and Instructional Services.
    c. Civic Safety Services. The law enforcement elements of this mission are much in need of a national communications network to enhance their operations.
    d. Biomedical Communications Network Services. A great deal of emphasis has been placed on improving communications services for the medical community. Any undertaking in this field should include consideration of the needs of government, medical institutions, medics, para-medics and patients.